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Environmental factors affecting burrowing of brown shrimp *Farfantepenaeus aztecus* and white shrimp *Litopenaeus setiferus*

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Introduction

Burrowing in the substrate by penaeid shrimps is a common behavior that appears to increase survival rates by protecting shrimp from fish predators (Fuss and Ogren 1966, Minello et al. 1987). Burrowing may also affect growth in penaeid shrimps. Metabolic rates and oxygen consumption are reduced when shrimp burrow (Lakshmi et al. 1976 , Egusa 1961), and it has been suggested that periods of burrowing and inactivity during the day may result in increased energy efficiency and increased growth rates (Moller and Jones 1975, Lakshmi et al. 1976). However, if the benefits of burrowing are primarily protective, the time engaged in this behavior may simply reduce foraging time and subsequently reduce growth rates. A negative relationship between burrowing and growth is supported by an examination of shrimp species commonly used in mariculture such as *Litopenaeus vannamei, L. stylirostris, Penaeus monodon,* and *Fenneropenaeus indicus*; these species grow rapidly and seldom burrow (Hughes 1966, Moller and Jones 1975, Moctezuma and Blake 1981, Primavera and Lebata 1995). If both mortality and growth rates of shrimp are affected by burrowing, information on environmental factors that control this behavior should be useful in understanding shrimp population dynamics.

The two most common penaeids in the northern Gulf of Mexico are the brown shrimp *Farfantepenaeus aztecus* and the white shrimp *Litopenaeus setiferus*, and these species display different burrowing behaviors (Wickham and Minkler 1975). Brown shrimp burrow during most of the day and emerge to forage at night. Burrowing in this species is affected by light intensity (Wickham and Minkler 1975), temperature (Aldrich et al. 1968), salinity (Lakshmi et al. 1976), and substrate texture (Williams 1958). White shrimp have a similar diel activity pattern, but they burrow less than brown shrimp during daylight hours (Wickham and Minkler 1975). Aside from light intensity, few environmental factors have been shown to affect burrowing in white shrimp. In this paper we report on a series of laboratory experiments that examine the effects of size, density, salinity, substrate texture, hunger, and the presence of fish predators on the burrowing behavior of juvenile white shrimp and brown shrimp.

Methods

Shrimp were held under natural light conditions before experiments. Experiments were conducted in twelve rectangular tanks (58 cm x 149 cm) under fluorescent lighting (7-10 microEinsteins/sec/sq m). Shrimp were placed in randomly-assigned tanks the day before observations were initiated; at 0730 h, the lights were turned on, and observations of the percentage of shrimp burrowed (> 1/2 of their body beneath the substrate) were recorded hourly (starting at 0830 h) throughout the daylight hours. The standard experimental conditions included shrimp of 50-80 mm TL, ten shrimp per tank, salinity of 25 ppt, and a fine sand substrate (washed beach sand); shrimp were fed daily (each evening) before experiments began and no fish predators were present. The following levels of experimental factors were tested: salinity (5, 25, 40 ppt), approximate mean size (50, 75, 100 mm TL), substrate (fine sand course sand, crushed shell), density (5.8, 11.6, 23.1 shrimp per sq m), hunger (fed, starved), and predator (present, absent). Shrimp species were tested separately, and experiments were repeated on a second day; thus there were generally 8-12 replicate tanks used for each treatment combination. The observation recorded was the mean percentage of shrimp burrowed in a tank for the day, and an arcsine transformation was used before conducting an analysis of variance (ANOVA). The 5% significance level was used in tests, and a protected LSD was used to make comparisons among three means.

Results

In our control treatments (the standard experimental conditions listed above), the overall burrowing rate during the day from all experiments was 29.5% for white shrimp and 89.1% for brown shrimp. For both species, burrowing rates decreased significantly as the substrate became courser; the mean percentage of brown shrimp burrowed in fine sand, course sand, and crushed shell was 89%, 22%, and 8%, while white shrimp only burrowed in fine sand (12%). Brown shrimp burrowing was marginally affected by salinity with the lowest burrowing rates at 5 ppt; white shrimp burrowing was not significantly affected by salinity. Large brown shrimp burrowed more than small and medium sized shrimp, but size did not significantly affect burrowing of white shrimp. There was no significant density effect for brown shrimp, but the percentage of white shrimp burrowed was significantly lower in the high-density tanks (11%) compared with the medium (45%) and low (38%) density tanks. The presence of a fish predator in the tanks did not affect burrowing of either species, but hunger level significantly affected burrowing for both species. In these experiments, half of the shrimp were starved for 5 days before the experiment was initiated. No food was present in experimental tanks until 1400 h when food was added. For brown shrimp, there was no difference in burrowing behavior between fed and starved animals until food was added to the experimental tanks; burrowing rates of starved shrimp (62%) were then significantly lower than for fed shrimp (90%). Starved white shrimp, however, had significantly lower burrowing rates (11%) compared with fed shrimp (32%) regardless of whether food was present or absent.

Discussion

Burrowing of brown shrimp and white shrimp is likely to provide protection from predatory fishes and from fishing nets used by predatory humans. Our results show that aside from the presence of fish in the tanks, all of the environmental factors we tested affected burrowing in at least one of these species and therefore could affect predation rates and sampling or catch efficiency of nets. In addition to light and temperature mentioned earlier, other environmental factors shown to affect burrowing of penaeids include dissolved oxygen (Egusa and Yamamota 1961), water depth/pressure (Hughes 1966, Wickham 1967, Vance 1992), water ammonia concentrations (Allan and Maguire 1995), and the type of seagrass (Kenyon et al. 1995).

Any interaction between burrowing and growth of penaeid shrimp is likely to depend upon the activity of emerged shrimp. If shrimp spend a large proportion of their emerged time foraging, growth should be inversely related to burrowing. Inherent growth of white shrimp is generally considered greater than that of brown shrimp (see review by Knudsen et al. 1977), and this difference is coincident with reduced burrowing in white shrimp. Food quality may also be involved in this relationship. Carnivorous shrimp that feed on high-quality food items may need less foraging time compared with omnivorous shrimp that feed on more refractory and less easily assimilated foods. Brown shrimp appear to be more carnivorous than white shrimp (McTigue and Zimmerman 1991, McTigue 1993).

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